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A FINAL TECHNICAL REPORT

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
SOLAR SYSTEM EXPLORATION DIVISION
PLANETARY ATMOSPHERES PROGRAM

A PROPOSED STUDY OF THE OUTER PLANETARY SYSTEMS USING THE PIONEER AND VOYAGER EXTREME ULTRAVIOLET DATA (OPDAP)

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Summary of the OPDAP Project

This entire project was made possible by the presence of four deep space spacecraft Pioneers 10 and 11 and Voyagers 1 and 2. These spacecraft were first the man made objects to fly by the giant outer planets, Jupiter, Saturn, Uranus and Neptune. The UV photometers on board Pioneers 10 and 11 and the UV spectrometers (UVS) on board Voyagers 1 and 2 have given us an unprecedented look at the outer planets in the far ultraviolet (FUV) and extreme ultraviolet (EUV). There is thus available a large UV data base containing information about the outer planets and their satellites. The interpretation of the UV data, however, has been anything but easy. This is because the outer planets and their satellites have proved to be very complicated and highly dynamic systems. Some examples of this will now be given. It was found that all the outer planets emit an anomalously high Ly-α glow from their dayside equatorial region which can not be simply explained by energy deposition of sunlight. Yet, Pioneer 10 observed a very dim Jupiter at Ly-α wavelength only $1/15^{th}$ the intensity observed by Voyager UVS. Pioneer 10 was the first to detect the Io torus, a ring of plasma surrounding Jupiter. However, while Pioneer 10 in 1973 observed a longitudinally asymmetric torus similar to that observed by Ulysses in 1992, Voyager UVS observed a complete torus in 1979. The Jovian satellite Io was found to exhibit volcanism and showed signs of an atmosphere. The subject of the anomalously high Ly-α glow and H_2 band emissions from the outer planets remains a controversial topic. It has been suggested that these excess emissions may be due to particle precipitation. The exact amount of this excess emission is also subject to debate due to known calibration differences between the Voyager UVS and the Pioneer 10 UV photometer at Ly-α.

A review of the cumulative publications given in the next section shows that over the

years the various papers and talks funded by this project have addressed the various issues mentioned previously. As early as 1981, S. Kumar studied the photochemistry of SO_2 in the atmosphere of Io and studied the possibility of a thick atmosphere on Io. Donald E. Shemansky and D.L. Judge have presented several talks and published papers on the physical condition of Jupiter's atmosphere and the Io torus plasma, on the electroglow phenomenon and on the change in particle excitation of Jupiter's atmosphere. There are also some papers on the atomic processes underlying planetary atmospheric emission. In addition, there are papers on the interplanetary glow which we are using as a transfer standard to establish the relative calibration between the Pioneer and Voyager spacecraft.

Cumulative Publications

1. Kumar, S., Photochemistry of SO_2 in the Atmosphere of Io and Implication on Atmospheric Escape, J. Geophys. Res., 87, A3, 1677, 1982.

2. Wu, F.M., and D.L. Judge, H_2^+ Ultraviolet Emission from Jupiter, paper presented at the Spring AGU Meeting, Baltimore, Maryland, 1981.

3. Kunc, J.A., Contribution of Dissociative Processes to the Production of Atomic Lines in Hydrogen Plasmas, J. Quant. Radiat. Transfer 33, 1, 1985.

4. Judge, D.L., and J.A. Kunc, Radial Energy Distribution of the Low Energy Protons in Io's Atmosphere, Planet. Space Sci. 31, 1157, 1983.

5. Shemansky, D.E., D.L. Judge, and J.M. Jessen, Pioneer 10 and Voyager Observations of the Interstellar Medium in Scattered Emission of the He 584Å and H Lyα 1216Å Lines, Proceedings of IAU Symposium 81, University of Wisconsin, Wisconsin, 1984.

6. Shemansky, D.E., D.L. Judge, and J.M. Jessen, Pioneer 10 vs. Voyager Experiments in the EUV, and the Nature of the Interstellar-Interplanetary Medium, in Local Interstellar Medium, IAU Colloquium No. 81, NASA CP-2345, p.24, 1984.

7. Shemansky, D.E., and D.L. Judge, The Physical Condition of Jupiter's Atmosphere and Io Torus Plasma in 1973/74, paper presented at the Spring AGU Meeting, Baltimore, Maryland, 1985.

8. Judge, D.L., and D.E. Shemansky, The Evidence for Change in Jupiter's Upper Atmosphere and Magnetospheric Energy Deposition Over the First Half of Solar Cycle 21, paper presented at the 17th Annual Meeting of the DPS, Baltimore, Maryland, October 28 - November 1, 1985.

9. Shemansky, D.E., and D.L. Judge, Evidence for Long Term Variation in Electroglow

Energy Deposition on Jupiter, DPS-AAS Meeting, Paris, France, November 4-7, 1986.

10. Shemansky, D.E., and D.L. Judge, Evidence for Change in Particle Excitation of Jupiter's Atmosphere 1968-1979, J. Geophys. Res., 93, No(A1), 21, 1988.

11. J.A. Kunc, Determination of Electron Density and Temperature in Non-LTE Plasmas From Spectral Lines of Impurity Ions, J. App. Phys. 1988.

12. D.E. Shemansky and D.T. Hall, The Distribution of Atomic Hydrogen in the Magnetosphere of Saturn, 1989, J. Geophys. Research, 97, A4, 4143, 1992.

13. T.M. Tripp, D.E. Shemansky, G.K. James and J.M. Ajello, Collisional Excitation nd Radiative Properties of NII: The Strong Intercombination (^1D - $^3P^0$) Transition at 748Å, 1991, Ap. J, 368, 641.

14. P. Gangopadhyay, H.S. Ogawa, and D.L. Judge, Consistency between SC#21REF Solar XUV Energy Input and the 1973 Pioneer 10 Observations of the Jovian Photoelectron Excited H_2 Airglow, Proceedings of the Workshop on the Solar Electromagnetic Radiation Study for Solar Cycle 22, ed. by Richard Donnelly, Space Environmental Lab., NOAA ERL, 383, 1992.

15. F. Bagnal, D.E. Shemansky, R.L. McNutt Jr., R. Schreir, and A. Eviatar, The Abundance of O^{++} in the Jovian Magnetosphere, Geophys. Res. Lett., 19, 2, 79, 1992.

16. P. Blum, P. Gangopadhyay, H.S. Ogawa and D.L. Judge, Solar Driven Neutral Density Wave, Astron. & Astrophys., 272, 549, 1993.

17. D.T. Hall, D.E. Shemansky, D.L. Judge, P. Gangopadhyay, and M.A. Gruntman, Heliospheric Hydrogen Beyond 15 AU: Evidence for a Termination Shock, J. Geophys. Res., 98, A9, 15185, 1993.

18. P. Gangopadhyay and D.L. Judge, The Backscattered Lyman Alpha Flow Emission as a Signature of the Termination shock, Adv. Space Res., 13, 173, 1993.

19. F.M. Wu, P. Gangopadhyay, and D.L. Judge, Pioneer 10 Ultraviolet Photometer Observations of Jovian UV Emission in 1973, J. Geophys. Res., 100, A3, 3481, 1995.

20. H.S. Ogawa, C.Y. Robert Wu, P. Gangopadhyay, and D.L. Judge, Solar Photoionization as a loss Mechanism of Neutral Interstellar Hydrogen in Interplanetary Space, J. Geophys. Res., 100, A3, 3455, 1995.

21. P. Gangopadhyay and D.L. Judge, Model Insensitive and Calibration Independent Method for the Determination of the Downstream Hydrogen Density, submitted to J. Geophys. Res., 1996.